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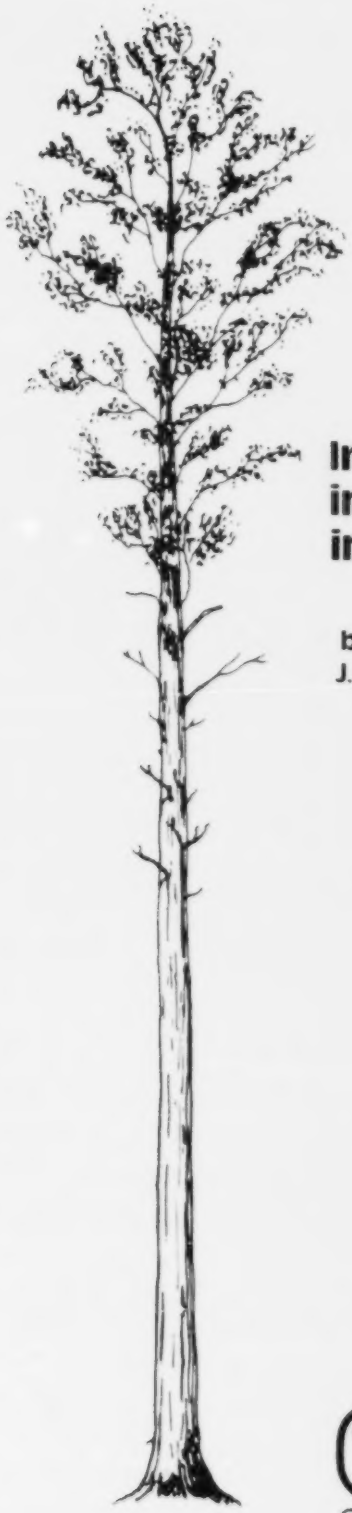

Incidence and volume of defect in second growth aspen stands in northern Ontario

by
J.A. Kemperman, N.F. Lyon and S.Navratil

Ontario
Ministry of Natural Resources
Hon. Leo Bernier
Minister
Dr. J. K. Reynolds
Deputy Minister

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J. A. KEMPERMAN, N. F. LYON, and S. NAVRATIL

Ontario Ministry of Natural Resources
Forest Research Branch
Northern Forest Research Unit
Thunder Bay, Ontario P7B 5G5

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ABSTRACT

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*Internal defect in aspen (*Populus tremuloides *Michaux) was assessed in 10 stands which originated on cutovers in northern Ontario during the mid 1940's. A total of 600 trees were sampled. The percent volume of wood affected by stain, rot, and combined defect was 1.4%, 0.5%, and 1.9%, while the incidence was 84%, 63%, and 96% respectively. Of 33 organisms isolated and identified from wood samples collected primarily at the 1.2 m (4 ft) level, four species of decay-causing fungi were encountered. The incidence of these fungi was low with the exception of* Peniophora polygonia *(Pers. ex Fr.) Bourd. and Galz. which was encountered in 44% of all stems at 1.2 m (4 ft). This organism, however, was associated only with stain or an incipient stage of rot, not advanced rot. Defect was not related to soil conditions, i.e. moisture regime and texture, with the exception of incidence of rot which increased 2.3-fold from moisture regime 0 to 3. The external characteristics of tree dominance, type of stub healing, and degree of natural pruning can be used to assess the relative internal quality of young aspen stands.*

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INTRODUCTION

Although considered a commercial tree species, trembling aspen (*Populus tremuloides* Michaux) has been traditionally under-utilized in Ontario. For the fifteen years prior to 1972, poplar (primarily aspen) quantities cut from Crown Land remained fairly constant at approximately 0.62 million cubic metres (22 million cubic feet) annually (Ont. Min. Nat. Res. 1969, 1974). Recently, utilization has increased to 0.89 million cubic metres (31.5 million cubic feet) in the year ending March 1974 (Ont. Min. Nat. Res. 1974). In contrast, the annual allowable cut for poplar in Ontario is 12.4 million cubic metres (444 million cubic feet) (Fitzpatrick and Stewart 1968).

In the immediate future, demand for aspen is expected to increase substantially. Keays et al. (1974) estimated that by year 2000 the demand for poplar products will exceed the current Canadian allowable cut for poplar of 39.7 million cubic metres (1413 million cubic feet). To be part of this expansion and to maintain its position as a major supplier of wood fibre, Ontario will be utilizing a larger portion of its aspen resource. Additionally, this aspen resource is becoming especially important, because the annual harvest of conifers is approaching its provincial allowable cut (Reynolds 1975).

With the increased demand for aspen, large acreages of hardwood and mixedwood stands will be harvested in Ontario. On most of these cutovers aspen will naturally regenerate by suckers from the residual parent root system (Horton and Maini 1964, Perala 1972), and within one year after harvesting, suckers can exceed 70,000 per hectare (28,000 per acre) and a height of 1.8 m (6 ft) (J. A. Kemperman, unpublished data). With such prolific and vigorous regeneration, aspen must be accepted and managed as the future crop in many areas, or an intensive program of conversion to or supplementation with other species will be required.

In accepting this natural regeneration, assurance is needed that these stands will develop to commercial maturity. One of the reasons for the past low utilization of aspen has been the high defect volumes in natural stands. In Ontario, the defect volume in relation to gross merchantable volume increases from 7.8% in the 21-40 year age class to 37.2% in the 121-140 class (Basham and Morawski 1964). Concern has been expressed that the wood defects, stain and decay, in the second growth aspen stands which develop on cutovers may even surpass the defect that is known to occur in mature and immature natural stands. The documented defect in natural stands and apparent defect in second growth stands has resulted in a common belief in Ontario that, "We must have some answers to the problem of decay in poplar before any intensive management of poplar can be justified" (Flowers 1970).

In 1970 a preliminary investigation by the Northern Forest Research Unit (Smith 1973) found that defect in aspen of the Terrace Bay District averaged 5-7% of total tree volume in 5-, 10-, 15-, and 20-year-old sucker stands that originated after logging. The percentage occurrence of trees with defect approached 100% by age twenty. The anomaly of high incidence combined with relatively low volume percentages indicated that

further research was needed before meaningful management predictions could be made. This subsequent study, conducted by S. Navratil while employed with the Ontario Ministry of Natural Resources at the Northern Forest Research Unit, was therefore an extension of the preliminary investigation and involved a detailed analysis of defect in second growth aspen on 25-year-old cutovers. Methodology was refined based on the earlier study and the identification of pathogens responsible for wood defect was emphasized. The mycological aspect, briefly included in this report, is a major part of a companion report by Basham and Navratil (1975).

OBJECTIVES

The objectives of this study were to determine in second growth aspen the following:

1. type, incidence, and volume of wood defect as a basis for predicting future stand quality,
2. causal organisms associated with wood defect as a basis for an assessment of the pathogens' future importance,
3. relationships between selected site conditions and wood defect as a basis for understanding defect variation among stands,
4. relationships between selected silvical characteristics and wood defect that would indicate internal wood quality without destructive sampling.

LOCATION AND DESCRIPTION OF STUDY AREA

The study area was located in the Terrace Bay District on the American Can of Canada Limited timber limits approximately 56 km (35 miles) southeast of Longlac, Ontario (Figure 1). This area lies on the boundary of Site Region 3E (Lake Abitibi) and 3W (Lake Nipigon) (Hills 1961) and was chosen because:

1. previous studies on wood quality had taken place in the same general locale (Basham 1958, 1960, Smith 1973),
2. American Can of Canada Limited is one of the few companies in Ontario that has consistently used large quantities of aspen and thus could supply a range of cutover conditions,
3. the forest conditions of the area were considered reasonably representative of large sections of northern Ontario.

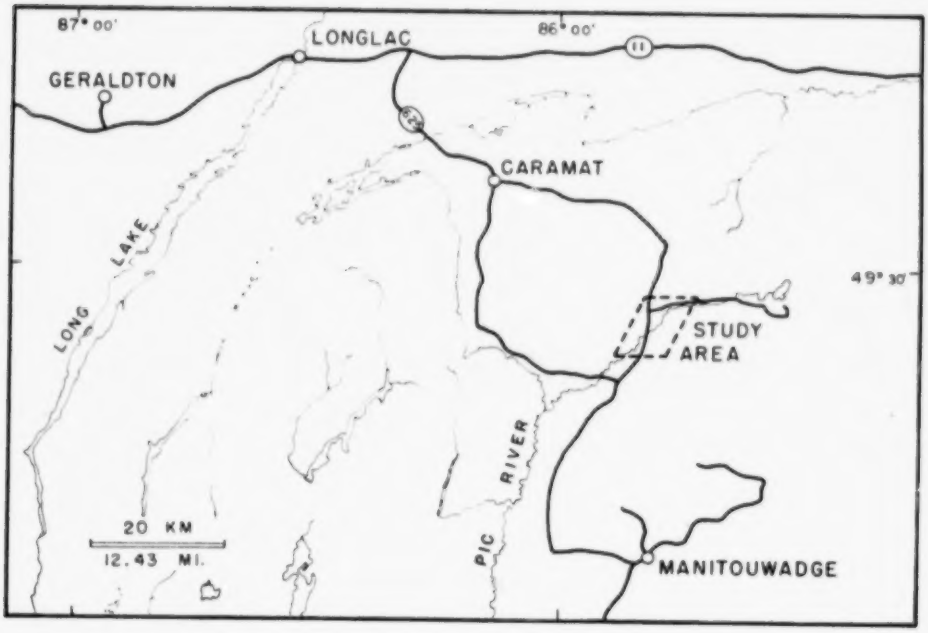

FIGURE 1. Location of study area, Terrace Bay District, Ontario.

The soils of the study area are generally podzolic but with a bleached A_2 horizon only on sandy materials. The parent materials are calcareous deposits of lacustrine clay, silt, and sand mixtures.

The parent stands were mixedwood forests with varying amounts of white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), balsam fir (*Abies balsamea* (L.) Mill.), jack pine (*Pinus banksiana* Lamb.), white birch (*Betula papyrifera* Marsh), balsam poplar (*Populus balsamifera* L.), and aspen. These stands developed following fires in the 1830's.[1]

In 1945 and 1946 the parent stands were manually clear cut with horse skidding. A wildfire occurred in a portion of the study area after the parent stands were cut but before regeneration had occurred. In subsequent years, all cutover areas regenerated naturally to the stands that were examined in this study. They consisted primarily of aspen with a minor component of other hardwoods and conifers. These stands were the oldest available cutover areas suitable for this study.

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[1] American Can of Canada Limited. Age Class Map - PIC Area 1965.

METHODS

In 1971, 10 stands were selected within the general study area where stand composition approached 100% aspen. In choosing the sample stands, a preliminary examination of the soil conditions ensured that a range of soil textures and soil moisture regimes was included in the sample. Based on relationships demonstrated by Smith (1973), the effects of original stand composition and age received only minor consideration in selecting the sample stands. Of the 10 stands studied, three were located in the burned portion of the study area. In each stand two strip plots were established. All plots consisted, with the exclusion of dead and suppressed trees, of 30 consecutive aspen stems within the strip. Plot width was 3.7 m (12 ft). Due to different stand densities, plot length varied from 12.8 m (42 ft) to 44.5 m (146 ft). In total 600 trees were sampled.

In the search for external indicators of internal quality, three silvical characteristics were assessed. Before felling, each tree was subjectively rated by i) dominance class (i.e. its height position relative to its neighbors) as intermediate, co-dominant, or dominant, ii) type of stub healing (i.e. the closure and configuration of callus and bark formation around the base of branch stubs, Figure 2), and iii) degree of natural pruning (i.e. persistence of dead branches, Figure 3). All trees were cut at ground level and then into 1.2 m (4 ft) lengths to a height of 4.9 m (16 ft) and into 2.4 m (8 ft) lengths above 4.9 m (16 ft) to a top diameter of approximately 3.8 cm (1.5 inches).

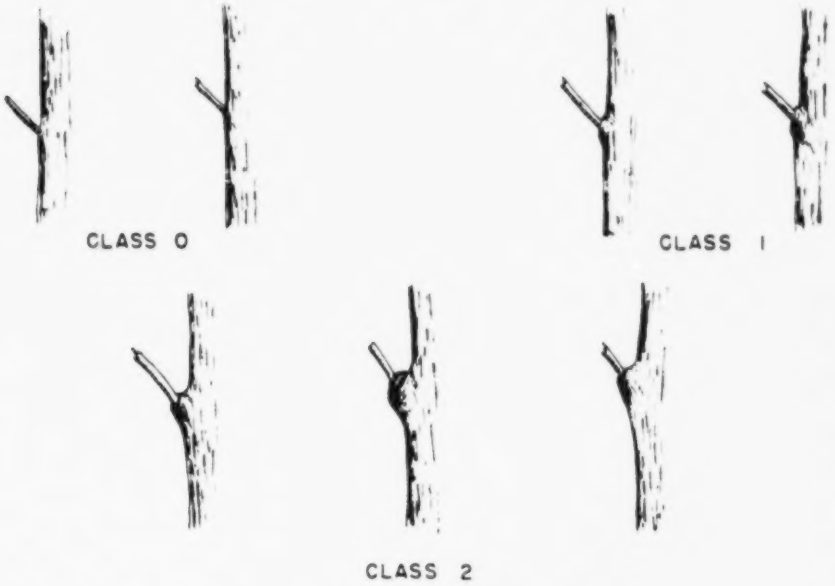

FIGURE 2. Stub healing classes with callus and bark formation around base of branch stubs protruding: 0 - very little if any above branch surface, 1 - less than 1.3 cm (0.5 inches), and 2 - more than 1.3 cm (0.5 inches).

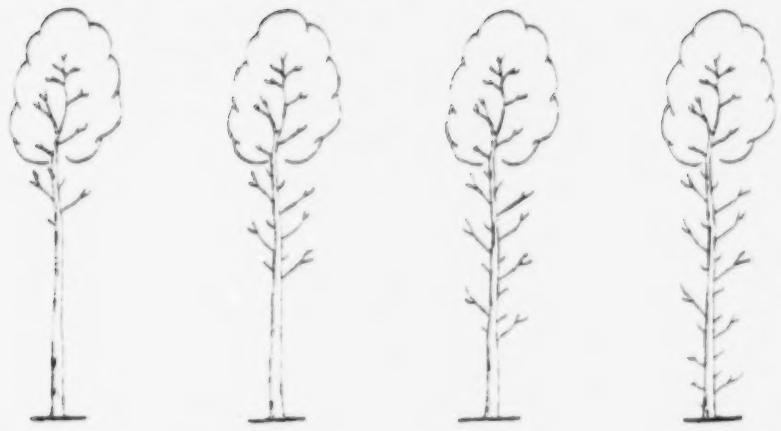

FIGURE 3. Natural pruning classes with dead branches and large branch stubs occurring on: 0 - upper 1/3 of stem below live crown, 1 - upper 1/2 of stem, 2 - upper 2/3 of stem, and 3 - greater than 2/3 of stem.

For both tree and defect volumetric determinations, a 2.5 cm (1 inch) disc was removed at each 1.2 m (4 ft) or 2.4 m (8 ft) level. The discs were placed in cold storage at the Northern Forest Research Unit in Thunder Bay. During the winter of 1971-72, the discs were removed from storage, dried, and sanded. Defect diameters and diameters inside and outside bark were measured and recorded for each disc. Defect was classified as stain, incipient rot, or advanced rot based on colour and wood hardness (Basham 1960). In all subsequent analyses, however, incipient and advanced rot were not differentiated. Tree ages were obtained by ring counts on the ground level discs.

For the mycological investigation, a 0.3 m (1 ft) bolt was cut from each tree at the 1.2 m (4 ft) level. From every fourth tree, this bolt was halved and one 0.15 m (0.5 ft) section was sent to the Great Lakes Forest Research Centre of the Canadian Forestry Service in Sault Ste. Marie, Ontario. An additional bolt was cut at ground level from 19 trees to sample defect below the 1.2 m (4 ft) level. The bolts, except those sent to Sault Ste. Marie, were placed in cold storage in Thunder Bay. During the winter 1971-72, these bolts were cut longitudinally and diagrammed including stain, incipient and advanced rot, and branch stubs. Isolation attempts were made primarily from defective wood with chips placed in test tubes containing a 2% malt agar medium. Preliminary identification of some isolates was made at Thunder Bay, however the majority were subsequently sent to the Great Lakes Forest Research Centre for final determination.

The 0.15 m (0.5 ft) bolts received by the Great Lakes Forest Research Centre during the summer of 1971 were immediately split and isolation attempts made with freshly exposed wood chips being placed on a 2% malt agar medium in test tubes. These isolates were also identified by Great Lakes Forest Research Centre staff.

For examination of possible relationships between site and internal wood quality, soil information was also collected at each plot. Soil profiles were diagrammed, and soil samples were collected from the B_2 and C horizons. The soil moisture regime was determined, based on criteria described by Hills (1950, 1952). In the laboratory, soil texture was determined by the hydrometer method. The percent silt plus clay content of the B_2 horizon was calculated for each plot.

Volumetric calculations and subsequent statistical analyses were based on 595 of the 600 trees sampled. Five trees were eliminated due to missing data. Tree and defect volumes were calculated by Smalian's formula (Avery 1967) using interval disc measurements. Regression analysis was used to assess relationships between average percent defect volume and soil moisture regime and texture (percent silt plus clay) of the B_2 horizon. Relationships between defect volume and dominance class, type of stub healing, and degree of natural pruning were assessed by t-tests as were the differences in tree and stand characteristics between the burned and unburned plots.

RESULTS

Stand, tree, and defect characteristics are summarized in Table 1. Individual plot information is presented in Appendix A. The average percent volume of wood affected by stain, rot, and combined defect (stain plus rot) was 1.4%, 0.5%, and 1.9% respectively. The incidence of stain, rot, and combined defect was 84%, 63%, and 96% respectively. All characteristics varied considerably among plots except tree age which averaged 23.3 years.

Isolation attempts at the Northern Forest Research Unit and the Great Lakes Forest Research Centre yielded either identifiable organisms or sterile cultures from 553 trees sampled at the 1.2 m (4 ft) level. Cultures from the remaining 47 trees in the 600 tree sample were not identified because of contamination or drying out of the cultures due to uncontrollable storage conditions. Isolation attempts were successful from all samples taken at ground level. Table 2 summarizes the incidence of all organisms identified. The incidence of decay-causing fungi isolated from the 1.2 m (4 ft) level was *Fomes igniarius* (L. ex Fr.) Kickx 1.1%, *Phlebia strigoso-zonata* (Schw.) Lloyd 1.8%, and *Peniophora polygonia* (Pers. ex Fr.) Bourd. & Galz. 44.3%. While frequently encountered, defect caused by *Peniophora polygonia* was either stain or incipient rot, never advanced rot. In many cases this pathogen was associated with dead branch stubs. The incidence of decay fungi from the ground level samples was *Armillaria mellea* (Vahl ex Fr.) Kummer 5.3% and *Peniophora polygonia* 15.8%. A detailed analysis of the mycological results was reported by Basham and Navratil (1975).

TABLE 1. Summary of aspen stand, tree, and defect characteristics based on plot averages

Characteristics	Mean	±	SD[a]	Range
Stand age - years	23.3	±	0.5	22.5-24.2
Total height - m	11.3	±	1.4	8.9-14.6
Diameter at breast height - cm	9.1	±	1.2	7.3-11.6
Total number of trees (all species) per hectare	4878	±	1720	2869-9192
Total number of aspen per hectare	4645	±	1855	2740-9192
Number of suppressed aspen per hectare	1174	±	876	179-2466
Number of intermediate aspen per hectare	454	±	320	0-1176
Number of dominant and co-dominant aspen per hectare	3017	±	1152	1537-5607
Volume per tree - dm^3	32.4	±	12.5	12.2-59.2
Volume per hectare - m^3	109.2	±	50.2	46.9-240.1
Percent stain volume per tree	1.37	±	0.95	0.25-3.52
Percent rot volume per tree	0.49	±	0.32	0.10-1.36
Percent defect volume per tree	1.89	±	1.10	0.35-3.87
Percent incidence of trees with stain	84.3	±	17.5	60.0-97.7
Percent incidence of trees with rot	62.7	±	23.8	26.7-100.0
Percent incidence of trees with defect	95.6	±	5.7	80.0-100.0

[a]Standard deviation of plot means.

TABLE 2. Incidence of aspen stems yielding organisms at the 1.2 metre and ground levels

Organisms [a]	Incidence at 1.2 m level (n = 553) %	Incidence at ground level (n = 19) %
Cephalosporium sp.	62.4	21.0
Bacteria	51.7	36.8
Peniophora polygonia (Pers. ex Fr.) Bourd. & Galz.	44.3	15.8
Cytospora sp.	6.5	0.0
Aspergillus sp.	6.0	0.0
Verticillium sp.	5.1	10.5
Yeasts	5.1	0.0
Cladiosporium sp.	4.3	15.8
Trichoderma sp.	4.0	5.3
Phoma sp.	3.8	0.0
Miscellaneous unidentified	3.2	0.0
Actinomycetes	2.4	0.0
Sterile cultures	2.2	0.0
Phycomycetes	1.8	5.3
Phlebia strigoso-zonata (Schw.) Lloyd	1.8	0.0
Libertella sp.	1.3	0.0
Rhinocladiella sp.	1.1	10.5
Fomes igniarius (L. ex Fr.) Kickx	1.1	0.0
Alternaria sp.	0.7	0.0
Gliocladium roseum (Lk.) Thom.	0.7	0.0
Beauvaria sp.	0.5	0.0
Pullularia pullulans (d By.) Berkh.	0.4	0.0
Coniothyrium sp.	0.4	0.0
Phomopsis sp.	0.2	0.0
Trechispora brinkmanni (Bres.) Rogers & Jacks.	0.2	0.0
Pleurostromella sp.	0.2	0.0
Hymenochaete tabacina (Sow. ex Fr.) Lev.	0.2	0.0
Stereum purpureum (Pers. ex. Fr.) Fr.	0.2	0.0
Coryne sp.	0.2	0.0
Fusarium sp.	0.2	0.0
Paecilomyces sp.	0.2	0.0
Monilia sp.	0.2	0.2
Phialophora sp.	0.2	0.0
Gloecystidiellum karstenii (Bourd. & Galz.) Donk	0.0	5.3
Armillaria mellea (Vahl ex Fr.) Kummer	0.0	5.3

[a] Decay fungi underlined.

Soil characteristics varied widely among plots (Appendix B). Soil moisture regime varied from 0 (moderately fresh) to 3 (moderately moist. Soil texture ranged from sand to silty clay loam. The percent silt plus clay content in the B_2 horizon ranged from 6% to 88%.

Regression analysis indicated that no significant linear relationships existed between the percent of tree volume affected by stain or rot and the soil moisture regime (Figure 4). Rot, however, did tend to increase and stain to decrease as moisture regime increased from 0 to 3. The incidence of stain was also not significantly related to moisture regime (Figure 5). The incidence of rot, however, did increase significantly (p=0.05) from 35% at moisture regime 0 to 79% at moisture regime 3 (Figure 5). Generally similar but weaker trends were indicated between the percent volume and incidence of stain and rot and the percent silt plus clay in the B_2 horizon (Appendix C). No statistical significance was found.

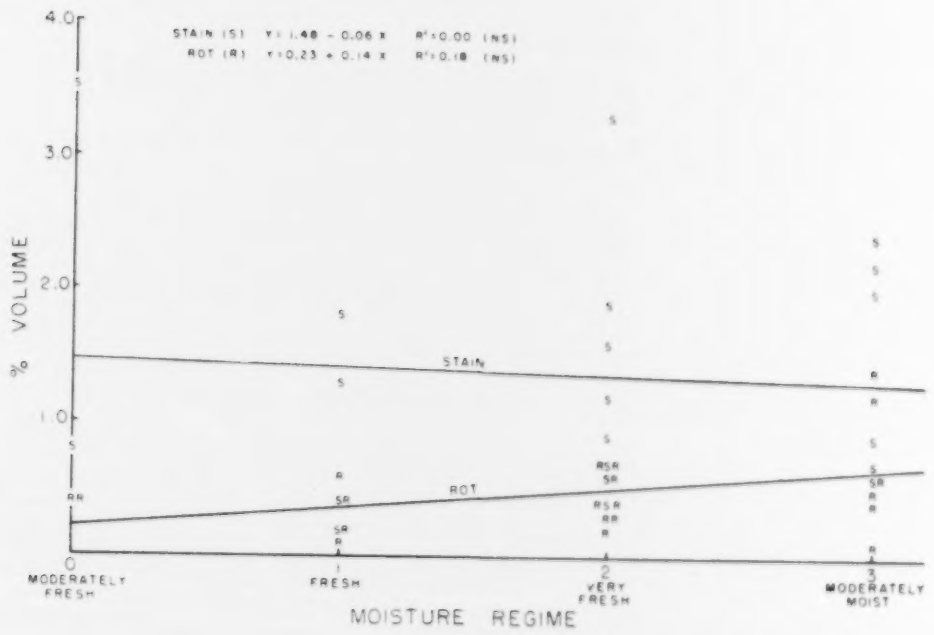

FIGURE 4. Percent of tree volume affected by stain and rot in relation to soil moisture regime (significance of regression: NS - not significant $p<0.05$).

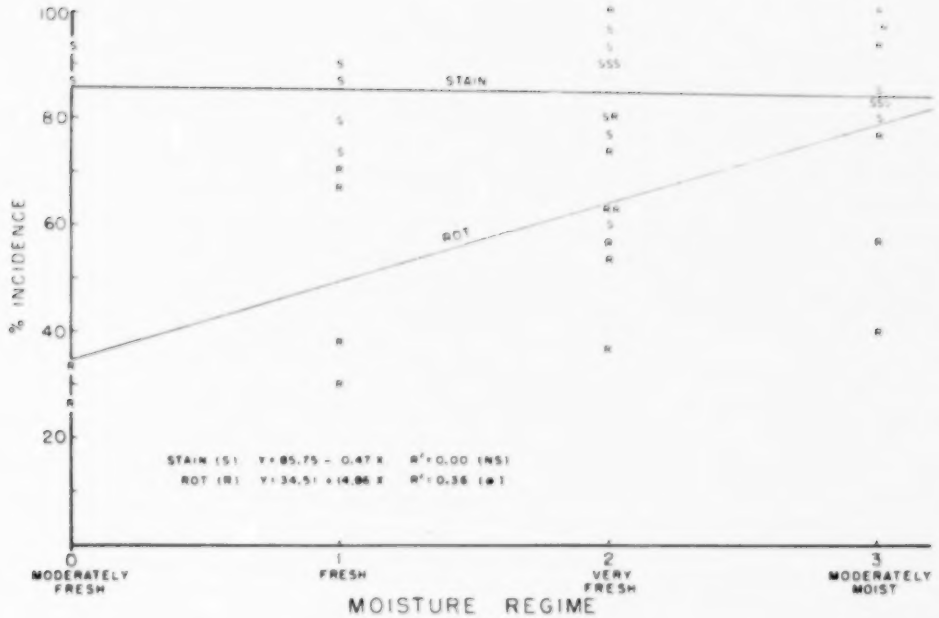

FIGURE 5. Incidence of stain and rot in relation to soil moisture regime (significance of regressions: NS - not significant, * - significant p=0.05).

In addition to internal stem defect, other tree and stand characteristics were compared to the different levels of soil moisture regime (Appendix D). Tree diameter, height, and volume increased significantly (p=0.05) as moisture regime increased from 0 to 3. The volume of aspen per unit area also increased significantly (p=0.05) with moisture regime, whereas the number of trees per unit area decreased although not significantly. Again, similar relationships occurred between the tree and stand characteristics and the percent silt plus clay in the B_2 horizon, but no statistical significance was evident (Appendix C).

On the six plots that burned immediately after the parent stand was cut, the percent volume of wood affected by stain, rot, and combined defect was 0.8%, 0.3%, and 1.1% greater respectively than on the 14 unburned plots. Of these, only the combined defect was statistically significant (p=0.05). There was no significant difference between the burned and unburned plots in the incidence of stain, rot, and combined defect, average tree height, or volume and density of aspen per unit area.

Relationships existed between defect and the silvical characteristics of dominance class, type of stub healing, and degree of natural pruning (Figures 6, 7, and 8). Within the dominance classes, the percent volume of wood affected by both stain and rot increased as the dominance class decreased. The percent volume of stain and rot in intermediate trees was 2.2- and 3.3-fold greater than in dominant trees (Table 3). Within the stub healing classes, the percent volume of stain was least in trees with an intermediate development of callus and greatest in those trees with the largest callus formations (Table 3). The percent volume of rot was similar in the trees with the least and intermediate callus formations but approximately doubled in trees with largest formations (Table 3). Within the natural pruning classes, the percent volume of stain did not change significantly. The percent volume of rot, however, nearly doubled as the degree of pruning decreased from the best to least pruned classes (Table 3).

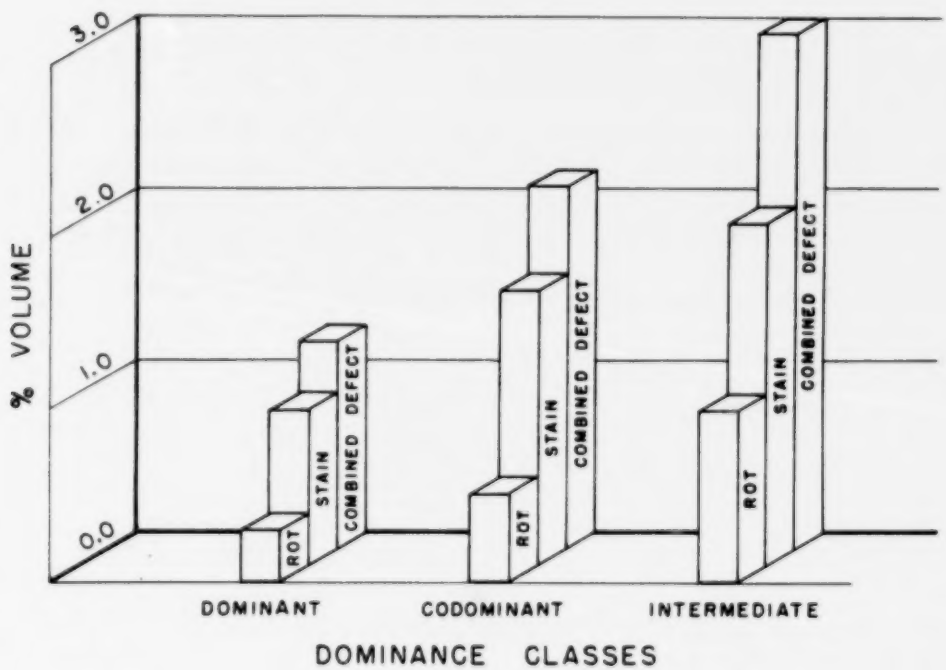

FIGURE 6. Relationship between the percent of tree volume affected by stain, rot, and combined defect for the dominance class.

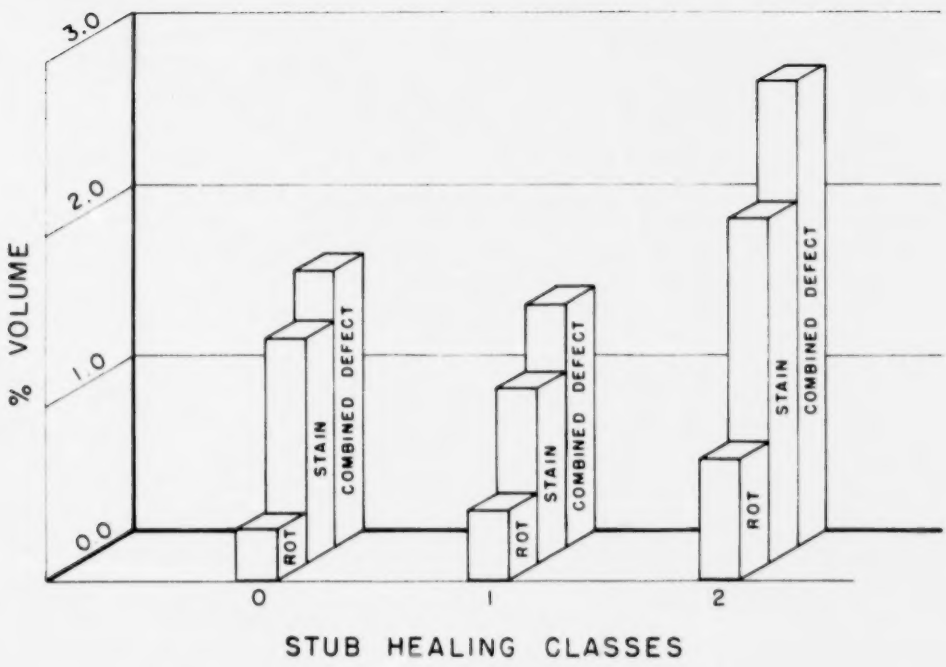

FIGURE 7. Relationships between the percent of tree volume affected by stain, rot, and combined defect for the stub healing classes.

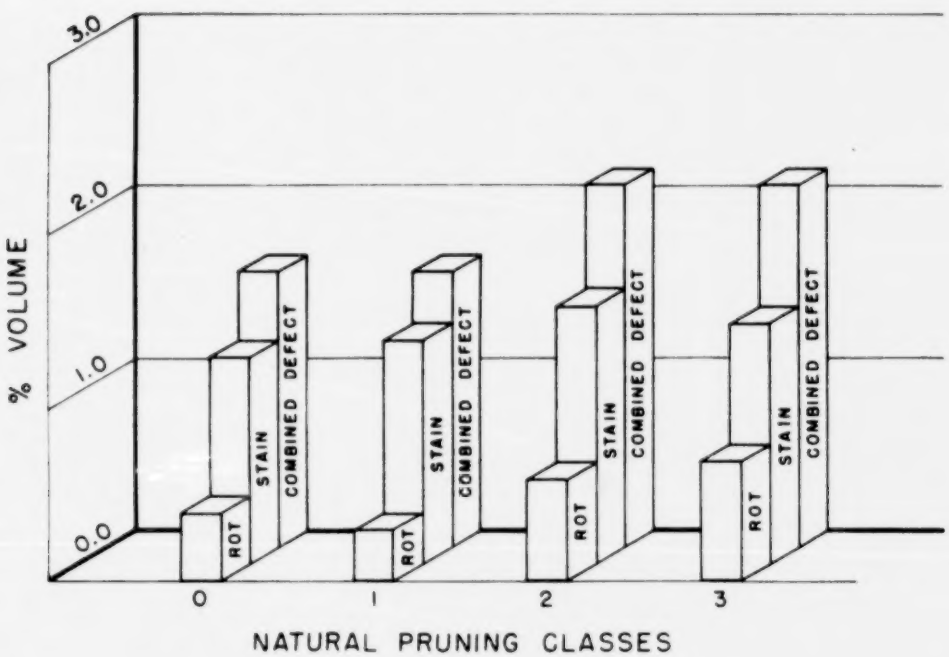

FIGURE 8. Relationship between the percent of tree volume affected by stain, rot, and combined defect for the natural pruning classes.

TABLE 3. Percent of tree volume affected by stain, rot, and combined defect in relation to silvical characteristics

Characteristic	Stain*	Rot*	Combined defect*
Dominance class			
Dominant (n=230)	0.9 a	0.3 a	1.2 a
Co-dominant (n=283)	1.6 b	0.5 b	2.1 b
Intermediate (n=82)	2.0 b	1.0 c	3.0 c
Stub healing class			
0 (n=53)	1.3 ab	0.3 a	1.6 a
1 (n=322)	1.0 a	0.4 a	1.4 a
2 (n=220)	2.0 b	0.7 b	2.7 b
Natural pruning class			
0 (n=106)	1.2 a	0.4 ab	1.6 a
1 (n=226)	1.3 a	0.3 a	1.6 a
2 (n=198)	1.5 a	0.6 b	2.1 a
3 (n=65)	1.4 a	0.7 b	2.1 a

*Common letters indicate no significant difference among the levels of a silvical characteristic within a defect classification (t-test, p=0.05).

DISCUSSION

While it has not yet been demonstrated in northern Ontario that second growth aspen originating on cutovers will develop into commercially mature stands, the results of the current study justify a degree of optimism. The volume of wood affected by rot was only 0.5%, most of which was in an incipient rather than advanced stage. Stain affected 1.4% of wood volume. In contrast, the percent volume of rot and stain was 1.0% and 12.6% in the youngest age class (41-60 years) of the original uncut stands studied by Basham (1958, 1960) in the same area. Relative to the older stands, the 23-year-old second growth aspen does not appear overly defective. The extent to which additional defect will develop as the stand advances to a harvestable age is not yet known.

The high incidence of defect encountered in the 23-year-old sucker stands of the current study is similar to that reported by Smith (1973) in stands aged 5-20 years in the same area. The percent volume, however, is 2.5- to 3.5-fold less than in the younger stands. This difference appears to be large especially since such factors as soil and stand history were similar in the two studies.

A portion of this difference may be attributed to sampling procedures. Smith's (1973) study classified all trees as either suppressed or dominant while the current study excluded suppressed trees and classified all others as intermediate, co-dominant, or dominant. The earlier study, therefore, included a greater proportion of the more defective smaller trees. Also a re-examination of the plots established by Smith (1973) revealed that part of the study area had been damaged by hail previous to the study. This could have resulted in abnormally high defect levels. Another source of variation between these studies is the subjective nature of classifying defect. Classification of wood into stain and rot categories is based on colour and wood hardness. Both characteristics occur in a continuum from sound wood through to advanced decay, but division of this continuum into distinct categories will vary with individual researchers.

It is also possible that the percent volume of wood affected by defect may periodically decrease due to periods of intensive natural thinning. The early development of aspen stands follows a cyclical pattern of vigorous growth followed by stagnation, rapid natural thinning, and then subsequent vigorous growth of survivors (Graham et al. 1963). During the first 20-25 years of stand development, this cycle may occur several times. The periods of intensive natural thinning would remove a large portion of the defective suppressed and intermediate trees while the less defective dominant and co-dominant trees survive. The resultant stand could be temporarily less defective. Also, the vigorous growth rate of surviving trees could substantially exceed the growth rate of the trees' defect columns. This would further decrease the percent volume of wood affected by defect. It is, therefore, conceivable that the 23-year-old stands investigated in this study had recently undergone a period of natural thinning and thus were less defective than the younger stands

investigated by Smith (1973). This is nevertheless considered a short term condition, because in the older natural aspen stands of the general area and elsewhere in Ontario, defect has been found to definitely increase with age (Basham 1958, 1960, Morawski et al. 1958).

Although, as indicated in Table 2, there were 33 different organisms identified in this study, only a low number of them is currently considered pathologically important in forest management. This is the broad group of decay-causing fungi. Basham (1958, 1960) reported that four species of decay-causing fungi, *Fomes igniarius*, *Radulum casearium* (Morg.) Lloyd, *Pholiota spectabilis* (Fr.) Kummer, and *Armillaria mellea*, were most frequently associated with rot in the older stands. Of these, *Radulum casearium* and *Pholiota spectabilis* were not encountered in the current study. *Fomes igniarius* was isolated from only 1.1% of all trees and *Armillaria mellea* from only one of the 19 trees sampled at the ground level. Although the incidence of these fungi in the 23-year-old stands is low, their occurrence may actually be greater than indicated because of the sampling system used. Sampling for culture purposes was confined to the 1.2 m (4 ft) level for all trees and supplemented with 19 samples at ground level. While restricting the culture sample to primarily the 1.2 m (4 ft) level avoided subjectivity in bolt selection, a bias may have been introduced because *Fomes igniarius*, a trunk rot, occurs throughout the stem but often does not extend down to the 1.2 m (4 ft) level, and *Armillaria mellea*, a butt rot, occurs in the lower portion of the stem and may not extend up to 1.2 m (4 ft). Of the rot encountered in the 23-year-old trees, most was an incipient stage and associated with *Peniophora polygonia*. This fungus is generally considered incapable of causing advanced rot in aspen (Basham and Navratil 1975).

While the types of decay fungi present, the volume of defect, and the percent occurrence of defective trees are all important in managing any forest, predicting the number and quality of the ultimate crop trees must be of primary consideration. Of the current 3017 dominant and co-dominant aspen per hectare (1221 per acre) in this study (Table 1), 39.9% or approximately 1204 per hectare (487 per acre) were rot free. Assuming continued stand closure and barring excessive mortality of the rot free trees, this group is considered large enough to provide most of the 759 to 1018 trees per hectare (307 and 412 trees per acre) found in normally stocked 60-year-old Site Class I and II aspen stands (Plonski 1960). These of course will be supplemented by a portion of the trees with current rot that will also survive and develop into crop trees.

The effect of site may be important in the development of defect. In this study, the percent volume of wood affected by rot increased from soil moisture regime 0 to 3 (Figure 4). This increase, however, amounted to a difference of only 0.3% and was not statistically significant. The original aspen stands 41 years and older that occurred in the vicinity of the current study had somewhat less decay on sites with soil moisture regime 2 than on either drier or wetter sites (Basham 1958, 1960). In

a larger sample of trees throughout Ontario, Morawski et al. (1958) found no conclusive evidence that soil moisture had an important influence on the extent of cull in aspen.

The incidence of rot, however, doubled as the soil moisture regime increased from 0 to 3 (Figure 5). Etheridge (1961) found that branch infections in aspen were almost twice as frequent on mesic as on dry sites. He attributed this to the greater mortality of young branches in mesic sites and to the susceptibility of these young dead branches to infection. Many of the micro-organisms associated with defect in the main stem of young aspens, such as *Peniophora polygonia*, enter via branch stubs (Basham and Navratil 1975). The increase of branch infections on fresher sites and the subsequent infection of the main stem by these micro-organisms could account for the 2-fold increase in the incidence of rot from soil moisture regime 0 to 3 observed in the current study. The incidence of stain, however, was unrelated to soil moisture regime (Figure 5). It is not yet known if stain-causing organisms are less affected by site conditions than rot-causing organisms. A portion of the stain also could have been of physiological rather than of fungal origin and thus possibly unrelated to soil moisture.

No significant relationships were found between either the present volume or the incidence of defect and the percent silt plus clay in the B_2 horizon. Within the range of textural conditions encountered in this study, defect appeared to be less related to soil texture than moisture regime. Although there are lacustrine clays in the general area, no plots occurred on the clay sites, and thus the effect of heavier soils on defect could not be assessed.

For the more operationally standard features of forest description, tree diameters, heights, volumes, and the volume per unit area of aspen all increased significantly (p=0.05) as soil moisture regime increased (Appendix D). These results compare favourably to the general conditions prevailing in Ontario where the best aspen growth generally occurs on sites with moisture regime 3 (Heeney et al. 1975). Tree diameters, heights, volumes, and the volume per unit area of aspen also increased, although not significantly, as the percent silt plus clay in the B_2 horizon increased. This measurement of soil texture has been used to assess site productivity (Stoeckeler 1960, Strothmann 1960) and has been correlated to site index for aspen (Meyer 1956). In the current study, the lack of a similar significant relationship between tree height and soil texture may be due to the relatively young age of these stands. As the stands develop, a relationship may stabilize between tree height (i.e. site index or site class) and soil texture. Differences among stands in soil fertility and other factors may also be obscuring any relationships between tree height and soil texture.

Site conditions as affected by fire had a negligible influence on the development of defect. The percent volume of wood affected by stain and rot was similar between the burned and unburned plots. The percent volume of combined defect, however, was significantly greater (p=0.05) in the burned plots but by only 1.05%. Nevertheless, this increase

in combined defect cannot be conclusively attributed to the effect of fire because of the small sample size, the range of unreplicated sites, and other possible confounding factors. The incidence of stain, rot, and combined defect, tree height, volume per unit area, and density were not affected by fire. The fire occurred before aspen suckers had developed, however had the cutover burned after suckers were present, the effect of fire on aspen quality may have been different. Repeated burning of aspen stands is known to reduce the abundance and vigor of suckers and the site index (Stoeckeler 1948, Buckman and Blankenship 1965).

The availability of reliable external characteristics to indicate the internal quality of an aspen tree would be of practical importance to foresters. The presence of *Fomes igniarius* fruiting bodies on the trunk of aspen is an indicator of white spongy trunk rot (Riley and Bier 1936, Basham 1958). Most forms of internal defect, however, do not have specific external indicators. In this study, the subjective external characteristics of tree dominance, type of stub healing, and degree of natural pruning all indicated a potential for assessing internal quality (Table 3 and Figures 6, 7, and 8). As only one age class has been examined and with the maximum difference in rot between the best and poorest levels of these characteristics at only 0.7% by volume, no firm recommendations for the practical use of these characteristics to estimate internal defect can be made. For general application, further investigation over a broad range of stand conditions and age classes is required.

As indicated in Table 1 and Appendix A, a wide range of variability was present in the stand and tree characteristics examined in this study. A portion of this variability has been related to site differences and silvical characteristics of individual trees. While not investigated in this study, the clonal growth habit of aspen could have also contributed to this variability. This growth habit is typical for aspen and results in stands being composed of mosaics of aspen clones (Barnes 1966). Clonal variation has been documented for many characteristics including growth rate (Zahner and Crawford 1965) and disease resistance (Wall 1971, Copony and Barnes 1974). Such clonal variation, therefore, could have accounted for a portion of the variability observed in this study. With clone size in the general study area averaging about 0.12 ha (0.32 acres) (J. A. Kemperman, unpublished data), individual plots could have contained trees from only one clone and, therefore, represent characteristics of only that particular clone. In such cases, the influence of the genetic factors due to the clonal growth habit would be indistinguishable from the environmental factors which were a main subject of this investigation. Research is currently underway to further define these relationships and to determine the extent of clonal variation of aspen in Ontario. The results of this work will help in determining those specific factors which influence the development of defect in aspen stands.

SUMMARY AND CONCLUSIONS

The degree to which stain and especially rot develop in second growth aspen stands is one of the most important single considerations potentially limiting the acceptance of natural aspen regeneration by forest managers responsible for the regeneration of cutover lands in Ontario. Stain and rot enter such aspen stands at an early age. By a stand age of 23 years, the incidence of both stain and rot is high. The volume of wood affected by defect on a percentage basis, however, is low as is the occurrence of serious decay-causing organisms. Most of the rot encountered was in an incipient stage caused by *Peniophora polygonia*. This fungus is considered incapable of causing advanced rot. While it is not possible to predict the extent to which defect will develop in the future, this study indicates that defect in second growth stands originating on cutover lands will probably not be greater than in natural stands of comparable age.

Only one definite relationship was indicated between defect and soil moisture regime or soil texture. The incidence of rot doubled as soil moisture increased from moisture regime 0 to 3. Average tree height, diameter, volume, and volume per unit area all increased significantly with soil moisture. The effect of moisture regime above level 3 cannot be predicted.

The external characteristics of tree dominance, type of stub healing, and degree of natural pruning can be used to indicate the relative internal quality of aspen stems. A rating system using these characteristics, however, is of limited value in young stands, because the actual volume of wood affected by defect is very low. The use of such a system in older stands may be of greater value but as yet has not been tested.

Based on the results of this study, it is concluded that the development of these second growth aspen stands will probably not be seriously limited by defect until they are at least 40-60 years of age. Depending upon future utilization standards, 40-60 year rotations should be considered for aspen. The limitations on rotation age as imposed by pathological factors, however, cannot be fully assessed until the second growth aspen stands approach a merchantable size.

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APPENDIX A Summary of stand, tree, and defect characteristics based on plot averages

Plot no.[a]	Age (yr)	Height (m)	Dbh[b] (cm)	Vol/tree Aspen (dm^3)	Trees/ha[c]	Aspen/ha excl. supp.	Vol/ha Aspen (m^3)	Stain Vol. %	Stain Incid. %	Rot Vol. %	Rot Incid. %	Combined defect Vol. %	Combined defect Incid. %
1	23.5	9.8	8.9	25.5	3010	1843	46.9	3.3	93.3	0.4	63.3	3.8	93.3
2	23.9	10.0	9.1	25.3	4024	1979	50.1	1.9	90.0	0.6	63.3	2.6	90.0
3	23.6	11.3	8.8	26.7	4901	3024	80.8	0.4	79.3	0.2	37.9	0.6	93.1
4	22.9	9.6	6.9	13.7	9137	5076	69.4	0.8	86.7	0.4	26.7	1.2	90.0
5	22.5	8.9	7.3	14.5	6079	4559	66.2	3.5	93.3	0.4	33.3	3.9	96.7
6	22.5	9.7	8.3	24.3	5862	5172	125.7	1.3	90.0	0.4	66.7	1.6	100.0
7	23.8	11.4	10.8	47.8	2870	2690	128.6	0.7	83.3	0.1	40.0	0.8	86.7
8	22.9	11.7	9.7	37.9	5147	4412	167.2	2.4	96.7	0.5	56.7	2.9	100.0
9	23.0	13.1	9.2	35.7	9193	6726	240.1	0.9	80.0	0.6	100.0	1.5	100.0
10	23.4	14.7	11.6	66.1	3754	2711	179.2	0.6	84.6	0.4	76.9	1.0	96.2
11	23.9	11.9	10.1	42.4	5128	3496	148.3	2.0	83.3	1.2	93.3	3.1	100.0
12	24.0	11.9	10.4	43.7	3820	2492	108.9	2.2	83.3	1.4	96.7	3.5	100.0
13	23.6	11.2	8.6	27.6	3746	2613	72.1	1.2	90.0	0.2	80.0	1.4	100.0
14	24.2	11.6	8.6	28.5	4250	3541	100.8	0.4	60.0	0.7	100.0	1.1	100.0
15	24.1	11.4	8.0	23.8	5413	4273	101.6	1.8	86.7	0.6	70.0	2.4	100.0
16	23.0	11.0	8.4	27.7	5005	3128	86.6	0.7	80.0	0.3	53.3	1.0	90.0
17	23.0	12.3	10.0	44.5	3767	2690	119.6	0.9	90.0	0.3	36.7	1.2	96.7
18	22.9	12.7	10.0	42.2	4798	3788	160.0	0.2	73.3	0.1	30.0	0.4	80.0
19	23.2	10.6	8.5	25.4	4484	3128	79.5	0.6	76.7	0.4	56.7	0.9	100.0
20	22.6	10.5	8.4	25.7	3175	2070	53.2	1.6	96.7	0.7	73.3	2.3	100.0

[a] Burned plots 5, 6, 11, 12, 15, and 16.
[b] Diameter at breast height.
[c] All species.

APPENDIX B Summary of site characteristics - plot averages

Plot no.	Soil moisture regime	Soil texture B_2 horizon[a]	% silt plus clay B_2 horizon
1	2	loam	71
2	2	silty loam	69
3	1	loamy sand	21
4	0	sand	8
5	0	sandy loam	29
6	1	silty clay loam	88
7	3	silty loam	75
8	3	silty clay loam	86
9	3	silty loam	84
10	3	silty loam	71
11	3	silty loam	84
12	3	silty clay loam	84
13	2	silty loam	65
14	2	sand	13
15	1	sand	6
16	2	silty loam	70
17	2	sandy loam	40
18	1	loamy sand	17
19	2	silty loam	81
20	2	silty loam	55

[a] From soil texture triangle (USDA 1951).

APPENDIX C Regression analysis of stand, tree and defect characteristics of aspen[a] related to soil texture (% silt plus clay B_2 horizon)

	Regression equation	R^2	Significance[b] level
Percent volume of defect			
Stain	$Y = 0.89 + 0.01 X$	0.08	NS
Rot	$Y = 0.31 + 0.00 X$	0.10	NS
Combined	$Y = 1.20 + 0.01 X$	0.12	NS
Incidence of trees with defect			
Stain	$Y = 78.84 + 0.11 X$	0.15	NS
Rot	$Y = 44.29 + 0.35 X$	0.19	NS
Combined	$Y = 93.51 + 0.04 X$	0.04	NS
Tree size			
Height (m)	$Y = 6.49 + 0.04 X$	0.04	NS
Dbh (cm)[c]	$Y = 10.83 + 0.01 X$	0.03	NS
Volume (dm^3)[d]	$Y = 23.28 + 0.17 X$	0.17	NS
Stand characteristics			
Trees/ha	$Y = 3656 - 3.0 X$	0.01	NS
Volume/ha (m^3)[d]	$Y = 78.6 + 5.8 X$	0.12	NS

[a] Excludes suppressed trees.

[b] Significance of regression based on F test, NS - not significant $p \cdot 0.05$.

[c] Diameter breast height (1.4 m).

[d] Includes bark.

APPENDIX D Regression analysis of stand, tree, and defect characteristics of aspen[a] related to soil moisture regime

	Regression equation	R^2	Significant[b] level
Percent volume of defect			
Stain	Y = 1.48 - 0.06 X	0.00	NS
Rot	Y = 0.23 + 0.14 X	0.18	NS
Combined	Y = 1.71 + 0.08 X	0.00	NS
Incidence of trees with defect			
Stain	Y = 85.75 - 0.47 X	0.00	NS
Rot	Y = 34.51 + 14.86 X	0.36	*
Combined	Y = 92.68 + 1.55 X	0.07	NS
Tree size			
Height (m)	Y = 9.62 + 0.86 X	0.37	*
Dbh (cm)[c]	Y = 7.30 + 0.93 X	0.60	*
Volume (dm^3)[d]	Y = 14.80 + 9.27 X	0.51	*
Stand characteristics			
Trees/ha	Y = 4104 - 320 X	0.06	NS
Volume/ha (m^3)[d]	Y = 61.0 + 25.4 X	0.24	*

[a] Excludes suppressed trees.

[b] Significance of regression based on F test, NS - not significant $p<0.05$, * significant at $p=0.05$.

[c] Diameter breast height (1.4 m).

[d] Includes bark.